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ORIGINAL ARTICLE

Improving the decision-making qualities of gaming simulations

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ABSTRACT
Gaming simulations (games) for policy and decision making have been the neglected "sibling" of educational and training games. The latter have experienced a widespread usage by practitioners and researchers, while the former have had limited, yet slowly increasing, adoption by organisations. As a result, various issues developing and using these games remain unaddressed. This includes the design of games, their validation, the actual game sessions, and applying the resulting knowledge from games in organisations. In this paper, solutions for issues identified in these four areas of gaming simulations are proposed. Solutions vary from purely analytical to purely social, stressing the interdisciplinary approach required to tackle the issues associated with them. The result consists of several theoretical and practical contributions as well as philosophical considerations regarding games for policy and decision making.

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Gaming simulations; decision making; complexity; knowledge management; game theory; validation; debriefing

1. Introduction

Gaming simulations, hereinafter referred to as games, have been closely related with systems, and particularly with systems characterised as complex (Wardaszko, 2018). Over the past decades we have witnessed an evolution of systems theory focusing on purely technical systems or social systems (Kornhauser, 1934), to socio-technical systems (STS) (Trist & Bamforth, 1951) and all the way to complex (adaptive) systems (CAS) (Holland, 1992). Within the increasing complexity of systems within our society, simulations and games can play an important role, as they offer us insight into the behaviour of the system and into the relation between interventions and performance. An interesting question to answer for complex systems is: What do games have to offer, that other tools do not, that can help us to understand systems?

Pure simulations, hereinafter referred to as simulations, have been perhaps the most popular tool for analysing systems. But as systems become more complex, and especially when that complexity is attributed to the bounded rationality of humans (Simon, 1957), it becomes cumbersome for simulations to capture the sometimes unpredictable behaviour of the increasing number of (human or organisational) actors within systems. Of course, the field of simulation is not static and major advances in areas like agent-based modelling (ABM) (Macal & North, 2010; Secchi, 2015, 2017) and Systems Dynamics (SD) (Akkermans & Van Oorschot, 2005; Li, Zhang, Guo, Ge, & Su, 2018; Morgan, Howick, & Belton, 2017) have taken place, modelling aspects of human or organisational activity that previously were not considered feasible. Nevertheless, these fields, and particularly ABM, are still evolving and have a long way to go until they can fully capture the richness of human activity (Bazghandi, 2012). This is perhaps the most critical limitation of analytical science, i.e. a set of quantitative data-intensive methods, with regards to analysing human-enabled systems, and a gap that games can fill, and have in many occasions have filled. Certainly, modelling methods like ABM and SD are also heavily used within games, not just simulations, and it would be a shortsighted to separate them from games. Still, games, on top of the simulation model and regardless of the method used to model the system under study, have the additional characteristic of including humans, which gives them the unique advantage of not just relying on stochasticity but also incorporating the actual human actors, who are part of the real system. Therefore, the answer to the question posed in the previous paragraph is that games can help us grasp, both on an individual and on a collective level, the richness and the subsequent complexity of systems through coupling the rigour of analytical science with the social problem-solving nature of design science (Klabbers, 2018; Raghothama & Meijer, 2018). This paper acknowledges the importance of modelling methods but is more concerned with understanding the unknown factors introduced by humans.

Despite games being a relatively mature field with more than 50 years of academic and applied history (Duke, 1974; Pruitt & Kimmel, 1977), it is still lacking systematic and rigorous methodologies for designing,

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validating, executing a game session, and managing the knowledge derived. While this holds for all types of games, this paper focuses on games for policy and decision making, hereinafter referred to as games for P&DM, and particularly applied for engineering systems. On the one hand, engineering systems are a typical example of CAS, due to their large scale, long lifetime, and close proximity to social systems, which evoke complex features such as adaptation, self-organisation, and emergence (Ottino, 2004). On the other hand, there are some distinct characteristics that differentiate games for P&DM from games for learning, situation awareness or hypothesis testing. In order to clarify the difference between P&DM games and other types of games, a characterisation of game types is needed. Being more focused on engineering systems, this paper adopts the characterisation proposed by Grogan and Meijer (2017) shown in Table 1.

The characterisation is based on two criteria, the type of knowledge generated by the game and the stakeholders who are the beneficiaries of this knowledge. With regards to the type of knowledge generated, the authors distinguish between two categories: i. *Generalisable*, meaning that the knowledge acquired during the game provides broad insights beyond the scope of a particular game scenario, and ii. *Contextual*, meaning that the knowledge acquired during the game provides deep insights closely related to a particular game scenario. With regards to the beneficiary of the generated knowledge, Grogan and Meijer (2017) again distinguish between two categories: i. *Participant*, meaning that the beneficiaries of the knowledge acquired during the game are the persons who play the game, and ii. *Principal*, meaning that the beneficiaries of the knowledge acquired during the game are stakeholders other than the participants, like decision makers, researchers etc. Games for P&DM are games that generate *contextual* knowledge and the knowledge beneficiary is the *principal*, in which case participants are usually experts on the role they play in the game.

It should be noted that this categorisation is not absolute, in the sense that the knowledge type and beneficiary are not boolean variables. Instead, the categorisation should be treated more like a continuum, where some games fall more in the Generalisable/Participant quadrant, hence considered to be more focused on learning, some other games fall in the Contextual/Principal quadrant, hence considered to be more focused on design or decision making, and so forth. Moreover, while the term *learning* can be interpreted in a broad sense, in this context *learning* refers to games that have been explicitly designed to teach a particular subject or curriculum. Hence, even though learning indeed happens when participants play a game for P&DM, the purpose of such a game is not to teach, and it is therefore distinguished from games for learning.

Table 1. Canonical applications of gaming methods (Grogan & Meijer, 2017).

Knowledge Type	Knowledge Beneficiary: Participant	Knowledge Beneficiary: Principal
Generalisable	Teaching	Research
	Experiential learning	Hypothesis generation and testing
	Dangerous tasks	Artefact assessment
Contextual	Policy	Design
	Organisational learning	Interactive visualisation
	Policy intervention	Collaborative design

In addition to the above characterisation, games for P&DM usually have a limited number, or even complete lack, of rules. The term *rules* does not refer to the rules governing the translation of a system into a game (Klabbers, 2009) but rather the freedom, or lack thereof, of players to explore different alternatives within the game environment. These games are also called open games (Klabbers, 2009). Open games have the unique advantages of offering a platform for exploration, where new and innovative ideas are pursued in a safe environment. Nevertheless, open games also come with their own unique challenges, one of which is the difficulty to facilitate a game of which the outcome is not just unknown but it also does not belong to a set of known outcomes.

Unlike games for learning/training, which enjoy a much more widespread adaptation resulting in an extensive body of knowledge in the policy and management domains (e.g., Barnabè (2016); Van der Zee and Slomp (2009)), games for P&DM are not described extensively in literature, because of their limited adaptation by organisations. Hence, this paper"s goals are first to provide a clear understanding on the complexities of games for P&DM and then, based on research gaps identified by Roungas, Meijer, and Verbraeck (2018f), to describe solutions for four aspects of the game lifecycle; design, validation, game sessions, and knowledge management. These four areas of inquiry were chosen because they cover the whole lifecycle of games (Roungas, 2019), in the sense that a game starts with the design, part of which are the requirements; then the game should be validated, in order for its results to be credible; a game session is the core of a game"s lifecycle; and finally, knowledge management is where the results of a game are put into action. Each area as such can be found in literature, but to the best of our knowledge, this research describes their joint analysis for the first time. These four areas do not necessarily follow a linear, waterfall-like, timeline; they regularly intertwine and provide feedback to each other, which is also discussed later in this paper. The aim of the paper is twofold: i. propose solutions to gaps identified, extending the current relatively limited literature, and ii. bridge the gap between the design and analytical communities by acknowledging their incompatibilities and then providing a fertile ground for discussion and future research. The second aim stems from the increased complexity of modern systems, explained in detail in Section 2, which asks for new interdisciplinary methods to analyse them. Hence, this 2nd goal is connected with the 1st, in the sense that the proposed methods are interdisciplinary and aim at not only providing solutions to identified gaps but also at bringing awareness on the level of complexity and as a result, on the need and the potential benefits from the cooperation of the design and analytical communities.

In Section 2, the particularities of games for P&DM are described, while the complexity characterising them is explored in more detail. Section 3 to Section 6 propose solutions regarding the identified gaps, in the areas of design, validation, game sessions, and knowledge management, respectively. In Section 7, final remarks are made.

2. Complexity of games for policy and decision making

As mentioned in Section 1, games for P&DM:

(1) Accommodate contextual knowledge, in the sense that insights from a specific scenario cannot (usually) be generalised,
(2) Benefit the principal and not the participants, in the sense that the principal has a question that needs to be answered, and
(3) Usually are open in terms of freedom participants have to explore different alternatives.

As a result, these three characteristics influence the following four phases in game development and usage:

- *Design* is influenced by all three characteristics. The particular scenarios, the background of the participants and of any other involved stakeholder, and the freedom participants have within the game, dictate specific design choices. More details on these relationships can be found in Section 3.
- *Validation* is primarily influenced by the degree of freedom participants have. More freedom, or a more open game, usually translates to a less known set of outcomes, which in turn means it is more challenging to formally validate the game. More details on these relationships can be found in Section 4.
- *Game sessions* are influenced by all three characteristics. In Section 5, results from two rounds of interviews with game stakeholders, game designers, and facilitation experts are presented that show how game sessions in general and debriefing in particular are influenced by these three characteristics, but also how people within the community have opposing opinions.
- *Knowledge Management* is influenced by the quality and type of knowledge as well as from the knowledge beneficiary, who is the potential user of a knowledge management system. More details on these relationships can be found in Section 6.

In addition to the influence of the three characteristics, these four phases also influence each other. Game design choices can positively affect or inhibit validation depending on how the real system is translated into a game. Validation increases a game"s credibility, which in turn enables a game session to be more effective; and vice versa, a game session that is considered “successful” increases the games credibility and applicability, thus making it more valid. Finally, knowledge management is the “umbrella” that covers all aspects of games. As such, the methodologies associated with it should be tailored according to the design, validation, and game sessions, and should also take into account the complexity of games in general and of these phases in particular.

Several types and/or levels of complexity have been proposed aiming at capturing, studying, and addressing the complexity pertaining to decision-making processes. On the one hand, there is the so-called “objective” complexity, also known as system complexity (Özgün & Barlas, 2015), rooted in the engineering sciences (Hughes, 1986). On the other hand, there is the “subjective” complexity (Özgün & Barlas, 2015), derived from the social sciences Thissen and Walker (2013), and observed in decisions (Van Bueren, Klijn, & Koppenjan, 2003), actors (de Bruijn & Herder, 2009), and institutions (Van Bueren et al., 2003). While distinguishing between the “objective” and “subjective” complexity gives insights in the different elements of a process, it does not resolve the actual complexity of the process. The real complexity is represented by the interdependencies within and between the complexity levels (de Bruijn & Herder, 2009; Liu & Li, 2012). In this paper, we distinguish three types of complexity: technical, actor, and context complexity.

2.1. *Technical complexity*

The system under study can be viewed along three lines:

- *Functionally* organised in aspect systems (Veeke, Ottjes, & Lodewijks, 2008), each of which defines the main responsibilities for the actors related to that aspect.

- *Geographically* organised, in which case the system is divided into subsystems, each corresponding to a region.
- *Hierarchically* organised by distinguishing between, e.g., the operational and strategic levels.

The technical complexity of the system depends on the number of technical changes or uncertainties, but also on how the system is viewed. A change in one aspect of the system usually requires alignment with one or more of other aspects and subsequently for many subsystems to adapt, which in turn influences both the operational and strategic level.

2.2. Actor complexity

Decision-making processes for complex systems usually involve multiple actors with different perspectives and interests. These actors are not necessarily hierarchically organised, but often they are mutually dependent. As a result, they form a network of interdependencies. In such a network, the course of the decision-making depends on the behaviour of and interactions between these actors (de Bruijn & ten Heuvelhof, 2008). This results in an often messy, spaghetti-like interaction structure. Moreover, the formal organisational structures are often hierarchical, which might give some actors a special position, making the decision-making process even more difficult.

2.3. Context complexity

During the process of decision-making, both the network of actors involved and the content of problems and solutions might change over time. This dynamic behaviour is for a large part the result of many interdependencies (e.g., a change in one regional subsystem has effect on the national system, a change of actor"s A behaviour might impact the behaviour of actor B, etc.). Moreover, decision-making processes are always impacted by unforeseen external developments such as political decisions, media attention, and technical innovations.

Based on the analysis above, it becomes evident that complexity is not just the result of the increased size of systems, but is mainly caused by the numerous interdependencies. Even when these interdependencies are abstracted to a certain degree, they still bear a significant amount of complexity, which needs to be translated into game design choices. The resulting games for P&DM are therefore characterised by numerous and complex interaction structures for which researchers and practitioners have only limited knowledge on how to understand and model them. In Table 2, the four phases of game development and usage are shown in relation to the three levels of complexity of systems.

3. Design

Since the early days of game usage, there have been attempts to define and formalise game design. The vast majority of research has focused on the educational capabilities of games, and only a handful of researchers have proposed approaches for formalising the design of games for P&DM.

Duke (1974) proposed the use of conceptual maps combined with precise documentation of the design process. Such maps have the ability to ensure the games" correspondence with reality, ascertain that the appropriate level of abstraction is being adopted, and confirm that the corresponding proposals can be implemented in the game design. Harteveld (2011) discussed about balancing reality, meaning, and play in game design. For each of these three pillars, he proposed several ways to implement them successfully within a game. Harteveld (2011) implicitly utilises game theory in several ways, but not fully. The goal of the proposed framework in this section is to build upon his work, and more specifically to further develop the first pillar of its Triadic Game Design approach, i.e. reality.

Only a few, yet promising, attempts have been made towards explicitly utilising game theory in game design. Game theory does come with its limitations regarding the modelling of systems" complexity (Klabbers, 2018), the most important of which is the over-simplification of situations (e.g. 2 actors and 2 strategies), which in turn leaves out contextual elements and does not capture the dynamics of the process (Bennett, 1987). However, there have been various attempts to overcome this impediment, one of which is including the beliefs of actors (Bacharach, 1994). The notion of "Game Concepts" includes this broader approach, therefore game theory should not be dismissed altogether, as it can give insights on several aspects of systems, such as actors" interaction and (strategic) behaviour. Indeed several researchers consider game theory to be a useful tool for game designers (Bolton, 2002; Guadiola & Natkin, 2005; Mader, Natkin, & Levieux, 2012; Ritterfeld, Cody, & Vorderer, 2009; Salen & Zimmerman, 2004; Skardi, Afshar, & Solis, 2013; Sterman, 1989), due to its ability to structure a real-world process, thus allowing the analysis of different scenarios and providing a perspective of the possible actions. Perhaps the most in depth approach is by Salen and Zimmerman (2004) in which they explicitly use elements from game theory, like utility functions, strategies, and payoff matrices, in game design.

In this section, a framework for modelling and translating a real system into a game, using game theory, is proposed. The research gap the framework aims to address is the limitation in methodologies for identifying the problematic areas of systems that could

Table 2. The different complexities in each game phase.

Game Phases	Complexities		
	Technical	Actor	Context
Design	Analytical science	Behavioural science	Design science
		← Game theory (See Section 3) →	
Validation	Simulation layer (See Section 4)	Game layer (See Section 4)	Simulation & Game layer for the specific context (See Section 4)
Game Session	Open & Closed games	Participants & Principals Different background	Contextual & Generalisable knowledge
Knowledge Management	Explicit knowledge (See Section 6.1)	Tacit knowledge (See Section 6.1)	Context communicated through Personalisation (See Section 6.2)

benefit from games (Duke, 1980). The main assumption on the reason that this is not currently feasible is that game design is more artistic rather than scientific (Schell, 2014).

The advantages of the proposed framework are twofold. On the one hand, the utilisation of game theory addresses problems related to game design, such as time constrains, cost, required experience, and mistakes in modelling. On the other hand, formalisation of game design facilitates the understanding of the intrinsic complexities of systems and games, as analysed in Section 2, which in turn enables the use of formal methods in validating games.

3.1. Framework

The proposed framework consists of: i) a methodology for abstracting the Real System and describing it through one or more Game Concepts, derived from game theory; and ii) a list of Game Concept elements and, linked to it, the corresponding list of game design decisions. Establishment of the links is attempted through the use of the characteristics of the Game Concepts (actors, strategies, issues, etc.) and the different game design decisions (scenarios, goals, etc.).

The framework is depicted in Figure 1 and contains five blocks:

- The *Real System* represents the real-world system that the game aims to imitate. The Real System contains actors operating in and on the system, as well as dynamics created by the interaction between the system and the actors. Depending on its complexity, the system can be characterised as either a complex adaptive system or a socio-technical system.
- The *Game Concepts* contain characteristics from the toolbox called Game Theory (Osborne & Rubinstein, 1994) representing the game elements of the Real System under study. Game Concepts describe the interaction between and behaviour of actors who have to make a decision (Bekius, Meijer, & de Bruijn, 2018). Some Game Concepts are mathematically defined (e.g. Prisoners Dilemma (Rasmusen, 2007)), while others have only been observed empirically (e.g. a Multi-Issue game (de Bruijn & Herder, 2009)).
- The *Gaming Simulations* represent the game design decisions used in modelling the Real System, after taking into account the complexity of the system the game is being designed for.
- The *Characterisation* of Real System into Game Concepts is the first step in the methodological process. The resulting Game Concepts should enable identification of the problematic areas and worst-case scenarios within the system.
- The *Links* between Game Concepts and games is the second step in the methodological process. This is the part that is more directly connected with Harteveld (2011) and with his Triadic Game Design, since it is the one that eventually leads to game design recommendations.

The dashed arrow represents the game design literature as of to date, thus making the contributions of this framework even more explicit. The direct link from the Real System to the Game Concepts shows that game design is usually based on the experience of game designers and rarely based on formal methods.

3.2. Methodology

The methodology consists of two parts, the rectangles in Figure 1: Characterisation and Links. Due to space limitations in this paper, each part is described briefly though more details can be found in the provided references.

With regards to the *Characterisation*, the taxonomy of Game Concepts, which is described in more detail in Bekius and Meijer (2018), originates from both formal game theory and public administration, where the concept "game" has a richer and more descriptive definition. The characteristics of Game Concepts therefore vary between being empirically substantiated and mathematically proven. The criteria used to design the taxonomy, which originate from theory on complex real-world decision-making processes (de Bruijn & ten Heuvelhof, 2008; Koppenjan & Klijn, 2004; Teisman & Klijn, 2008), are important for selecting the *right* Game Concepts. Multiple actors are usually involved in these processes, forming a network

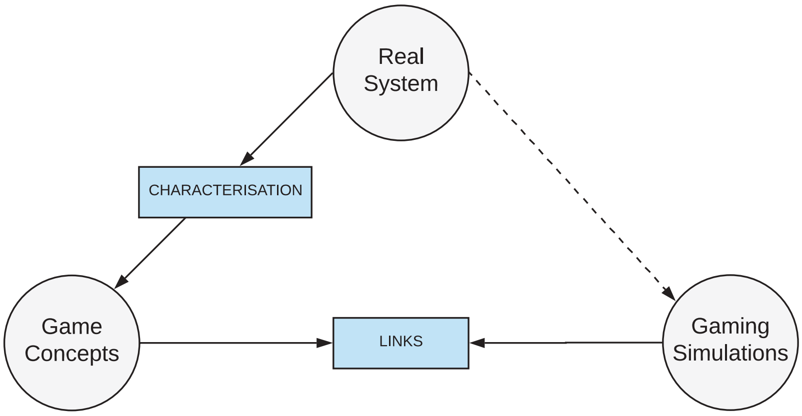

Figure 1. Framework for characterising the real system and linking the Game Concepts to game design decisions.

of interdependencies. Hierarchical relations can exist within those networks most frequently between two actors (Bekius & Meijer, 2018). With regard to games, the game theory notions help analysing the situation and "predicting" worst-case scenarios. Since such scenarios are undesirable, the ability to identify them in advance can be particularly helpful when making game design decisions.

With regards to the *Links*, which can be found in detail in Roungas, Bekius, and Meijer (2019), for the Game Concepts" characteristics, a list of 16 Game Concept elements, based on de Bruijn and ten Heuvelhof (2008); Rasmusen (2007); and Osborne and Rubinstein (1994), is used as a starting point. Whereas for the game decisions, additional literature is used in order to adapt and enhance the list of game elements for educational games, compiled by Roungas and Dalpiaz (2016), to fit games for P&DM. In addition to literature, two games from the Dutch railways were used to validate the corresponding lists (Roungas, 2019).

3.3. Case studies

The proposed framework was applied to three case studies. From the case studies, two were from the Dutch railways and also finished projects, and the third was from the Swedish healthcare system and is still an on-going project. The first two case studies were used in order to further validate the applicability of the framework, whereas the third one to test it on a future project.

The results from the case studies showed several areas that could improve from the application of the framework (Roungas et al., 2019). Specifically for games on an operational level, the framework indicated that participants should not only be from the operational layer of the organisation but also from management, thus engaging the actual decision-makers in the process. The framework was also able to provide a balance between complexity and realism by avoiding over-complex situations, where there are multiple issues per actor, which might also be conflicting, thus creating a realistic game while maintaining complexity at a reasonable level. Finally, in the last case, the framework was able to pinpoint the worst-case scenario in a quick and formal way, whereafter a game can be used to further explore and perhaps prevent bad scenarios from happening.

3.4. Final remarks on the design framework

The framework proposed in this section shows promising results with regards to addressing several problems related to modelling games. In addition to addressing those problems, a formalised approach to game design, such as the one proposed in this section, enables the use of formal validation methods. In turn, the application of formal validation methods allows for verifiable scientific results as opposed to the current empirical and perhaps biased assessments of experts.

4. Validation

Unlike pure simulations, games have a distinct characteristic, which is the human participation, or in other words games have a *Game Layer* on top of the *Simulation Layer*. Game validation, due to its nature of including humans, usually depends more on the subjective opinion of experts (van Lankveld, Sehic, Lo, & Meijer, 2017), e.g. using questionnaires, than formal methods. This limitation is related to the lack of design methods for games as well as to the usually low number of participants. The former was analysed in Section 3. The latter, i.e. the sample size, plays a significant role on the applicability of game results. A small sample size is easy to obtain, but has limited possibilities for deriving analytical conclusions, and thus provides limited possibilities for generalising the observations from the game. A large sample size, while solving the analytical problem and the generalisability of the results, is usually too expensive to obtain and also difficult to coordinate.

Validation of the *Simulation Layer* has been vastly researched through in the last three decades (Balci, 1998, 2004; Sargent, 1996), where numerous formal methods and statistical techniques have been introduced. Moreover, methodologies for first verifying that indeed the sample size is small (Lenth, 2001), then selecting the most appropriate validation methods and statistical techniques among the numerous existing ones (Roungas, Meijer, & Verbraeck, 2018d), and finally automating validation (Roungas, Meijer, & Verbraeck, 2018e) have been proposed. Furthermore, for games in which participants do not need to be physically present, technology can be used to reach a greater audience, thus increasing the sample size (Katsaliaki & Mustafee, 2012).

Validation of the *Game Layer*, however, due to its nature of including uncertainties pertaining to human activity, is usually not so straightforward. The formalisation of game design can provide more structure on game validation, as analysed in Section 3. With regards to the sample size, the *Game Layer* would benefit from knowledge management, analysed in Section 6, in the sense that the more game sessions are conducted the more evidence of a system"s behaviour are discovered and the cumulative sample size gradually becomes large enough to generalise the outcome of the game.

The aim of this section is not to propose one particular methodology for game validation but rather to pinpoint that in most cases, game validation is not as straightforward as the validation of simulations. While so far the analysis of game validation referred to the total set of games, the focus of this paper is on P&DM games, which need additional validation compared to games for teaching and training. Games for P&DM, particularly those imitating engineering systems, have a very dominant *Simulation Layer*. Therefore, these games should, and usually do, rely heavily on analytical methods. Still, since games, in general but also for P&DM, depend significantly on contextual and behavioural factors as well as on how the actual game is executed, the briefing, game session, and debriefing are of tremendous importance as well. Validation and game sessions have a reciprocal relationship. Increased validation is more likely to lead to a fruitful and more successful game session, and a successful game session boosts the game outcome and thus further increases its validity. But then the question that rises is: How is a *successful* game session ensured, particularly in games for P&DM?

5. Game sessions

Game sessions consist of three phases: briefing, gameplay, and debriefing, with the latter being considered the most important feature of games (Crookall, 2010). Nevertheless, their almost completely synthetic nature raises the question: are game sessions in general and debriefing in particular performed and analysed in a rigorous scientific way? In other words, are they consistently structured, given the different characteristics of games, and is it also clear what would constitute a successful game session and debriefing? The answer to all these questions is no (Roungas, De Wijse, Meijer, & Verbraeck, 2018a). The reason for this negative outcome is that expertise regarding game sessions and debriefing resides almost entirely in the tacit knowledge spectrum. As a result, knowledge and best practices on how to conduct fruitful game sessions and debriefing are either disseminated without understanding the causes for success, or not disseminated at all (Roungas, Lo, Angeletti, Meijer, & Verbraeck, 2018b). Hence, the aim of this section is make this tacit knowledge of experts more explicit, and to gain understanding on why certain practices are more prone to success than others. In order to accomplish this goal, two rounds of interviews were conducted.

The first round of interviews was with 19 experts of which 7 game designers, 6 project leaders, 4 game participants, and 2 department managers. The inclusion criterion for the interviewees was that they should have been stakeholders in at least two games within the last 5 years, in order to have a recent and holistic opinion. The primary tool for analysis was Q-methodology, while at a later stage Principal Component Analysis (Groth, Hartmann, Klie, & Selbig, 2013) and K-means clustering (Likas, Vlassis, & Verbeek, 2003) were used for further validating the results. In the Q-methodology, the results from the first four interviewees were used to build the q-sort statements, which the remaining 15 interviewees used. The results, shown in Table 3, revealed several factors that either boost or inhibit games" success.

The application of Principal Component Analysis was inconclusive, while the K-means clustering showed similar results with the Q-methodology, thus further validating the findings.

The second round of interviews was with 21 game facilitation experts, all of whom were members of ISAGA and having more than 15 years of expertise. This round of interviews was mainly characterised by the contradicting answers for almost all questions. This result translates to a non-unified approach towards games in general and debriefing in particular. The complexity characterising modern systems, as it was examined in Section 2, immediately excludes pure analytical methods as the absolute and only solution, as the probability for ludic fallacy (Taleb, 2004) increases significantly. Therefore, these interviews aimed to provide insights on how facilitation experts approach debriefing, and to tap into their tacit knowledge.

The questions these interviews intended to address were:

Table 3. Results from first round of interviews using the Q-methodology (Angeletti, 2018).

Factor	Impact	Comments
Presence of a game manager	+	A person who would attend all game-related procedures was found to be beneficial. These procedures involve choosing participants, making these participants available on the day of the game, managing missing players, taking care of the space and the infrastructure for the gaming session, to name a few.
Managerial guidance and involvement	+	The involvement of mid/high level managers made the participants feel that what they are doing during the game session matters and it is not just a game.
Structured and concrete results	+	While the limitation of analytical sciences have been pinpointed in this paper, complete absence of it is also detrimental. Apart from the lack of robust scientific methods for evaluating certain results, the absence of quantifiable results was found to be diminishing the credibility of the game itself.
Strict rules	+	Stricter rules were perceived by the interviewees as an insurance of higher validity of results.
High variety of roles involved in game design	+	Involvement of stakeholder not just during the game but also during the design process was appreciated by the interviewees, especially from operational personnel.
Simulator validated beforehand	+	Not properly validated software has created frustration among the stakeholders and negative opinion about the game overall.
Structured debriefing	+	Particularly for games for P&DM, an unstructured open discussion after the game was found to often distract from the goal of the game.
High complexity of the games scope	–	Due to time and budget restrictions, over-complex games should be avoided, in order for results to be obtained in an affordable and timely manner. Moreover, complex environments tend to overwhelm the participants causing the opposite effect from the desired one.
Unexpressed and/or conflicting stakeholders interests	–	Unexpressed interests and expectations were found to severely increase the risk of unanswered research questions and unclear results.
Time pressure	–	Time pressure was recognised as a factor that forces untested or not well tested simulators to be used in game session that often causes crashes in the software leading to negative appreciation on behalf of the participants and potentially invalid results.
Pressure from external actors (for obtaining a solution suitable to their interests)	–	Some stakeholders might put pressure on the game designers or facilitators to obtain results that fit their interests and agenda, which in turn can cause conflicts among the stakeholders, and potentially invalid results.

(1) Given the limitation of analytical methods to provide clear criteria for success of game sessions, how should success be defined?
(2) What is the level of knowledge of clients regarding their goal using games and how should they be prepared prior to the game session?
(3) How do facilitators adapt their approach to the game session based on the players" characteristics?

The first question yielded perhaps the most answers with regards to how experts define success. 21 interviews resulted in more than 10 different answers, confirming the lack of consistency in the field. Nevertheless, three answers were far more common than the others. Freedom and feeling safe to share your experience from the game was considered a factor of paramount importance provided by six experts. The second most frequent criterion for success was the degree to which players would actually implement the lessons learned during the game in their work. Finally, a success factor acknowledged particularly by game designers, was the level of involvement of players and their desire to play the game again.

The first part of the second question was initially expected to be answered overwhelmingly positive, but it turned out that clients often want to build a game but without knowing the actual goals. For the second part of the question, facilitators should manage the varying levels of awareness of clients, where facilitators inform the clients about the possible unpredictable results of open games, like games for P&DM.

The third question relates back to theory, where the interchanging roles that facilitators can, and should, take during a game, was introduced (Kriz, 2010). The first step for facilitators is to identify any knowledge gap of the players with regards to the game they will participate in. Then, when the participants feel safe enough during the debriefing, the facilitator should capitalise on that by taking the conversation into a deeper level. It should be noted that the interviewees acknowledged the influence of particular debriefing methods but none stood out as being most effective or preferred.

The two sets of interviews, analysed in this section, provide “inside” information on best practices when conducting game sessions and subsequently on debriefing. While analytical methods can provide invaluable insights when quantitative variables are available, the kind of knowledge provided in this section can only be attained by interviewing experts and then properly interpreting the results.

6. Knowledge management

Knowledge management (KM) and reuse of games is not, and should not be, of academic interest only. The effectiveness of a corporation depends heavily on how it manages and reuses knowledge (Markus, 2001), or in layman terms, how it obtains and thereafter maintains the so-called “know-how” (Roungas, Meijer, & Verbraeck, 2018c). As a corporation acquires and builds up on knowledge obtained through games, it improves its know-how, and thus sustains or even increases its competitive advantage (Dixon, 2000).

Despite the fact that games have proven to be cost effective, on multiple occasions they still involve a substantial financial cost (Michael & Chen, 2005). Moreover, time is required to process the game outcomes and come up with the best possible business decision. This additional time does not only increase the accrued costs but also delays decisions that sometimes are time-sensitive. All of the above combined with the lack of a comprehensive methodology for managing and reusing knowledge acquired through games, result in organisations, researchers, and game practitioners to "reinvent the wheel" by conducting consecutive and (almost) identical game sessions, accompanied by data analysis. The motivation for this study is therefore triggered by our strong belief that the capturing, compilation, maintenance, and dissemination of knowledge requires a methodology that will maximise the game outcomes concurrently with the minimisation of the associated costs and risks.

While there is a lack of literature in the area of KM of games, existing literature in the general area of KM creates a pathway towards KM of games. Therefore, based on this literature, which is illustrated in the forthcoming subsections, a knowledge management framework (KMF) is proposed. The KMF consists of several building blocks, each of which refers to a different aspect of the knowledge management system (KMS) and/or the organisation. These building blocks are the *Type of Knowledge* (Section 6.1), the *Strategy, Purpose, and Users of KMS* (Section 6.2), and the *Organisational Culture*. An illustration of the KMF is shown in Figure 2.

The latter, i.e. organisational culture, has a reciprocal relationship with KM. On the one hand, the cultural values within an organisation influence the way people experience the KM outcomes and force the underlined KMS to evolve (Alavi, Kayworth, & Leidner, 2005). On the other hand, KM shapes the organisational values (Alavi et al., 2005) and improves the organisational performance through the development of human capital (Hsu, 2008). As a result, the culture of an organisation with regards to KM defines the potential effectiveness of KM. Nevertheless, due to the scope and the size limitations of this paper, organisational culture is not further analysed, yet acknowledged as a crucial element of knowledge management.

6.1. Type of knowledge

Knowledge can be defined in a number of ways. One of the most widely used definition is the distinction between explicit and implicit, the latter also known as tacit, knowledge (Smith, 2001). According to this classification, explicit knowledge is considered to be data or information that is communicated in a formal language and/or digitally or printed information that can be shared, such as manuals. On the other hand, tacit knowledge focuses on the cognitive features of humans, such as mental models, beliefs, insights, and perceptions.

6.1.1. Explicit knowledge

Explicit knowledge produced in and from games can be of quantitative or qualitative nature. There are four phases, i.e., sources of explicit knowledge, in a game"s lifecycle.

The first phase concerns *game requirements*. Although requirements are usually considered to be relevant only for the game they are elicited for, according to

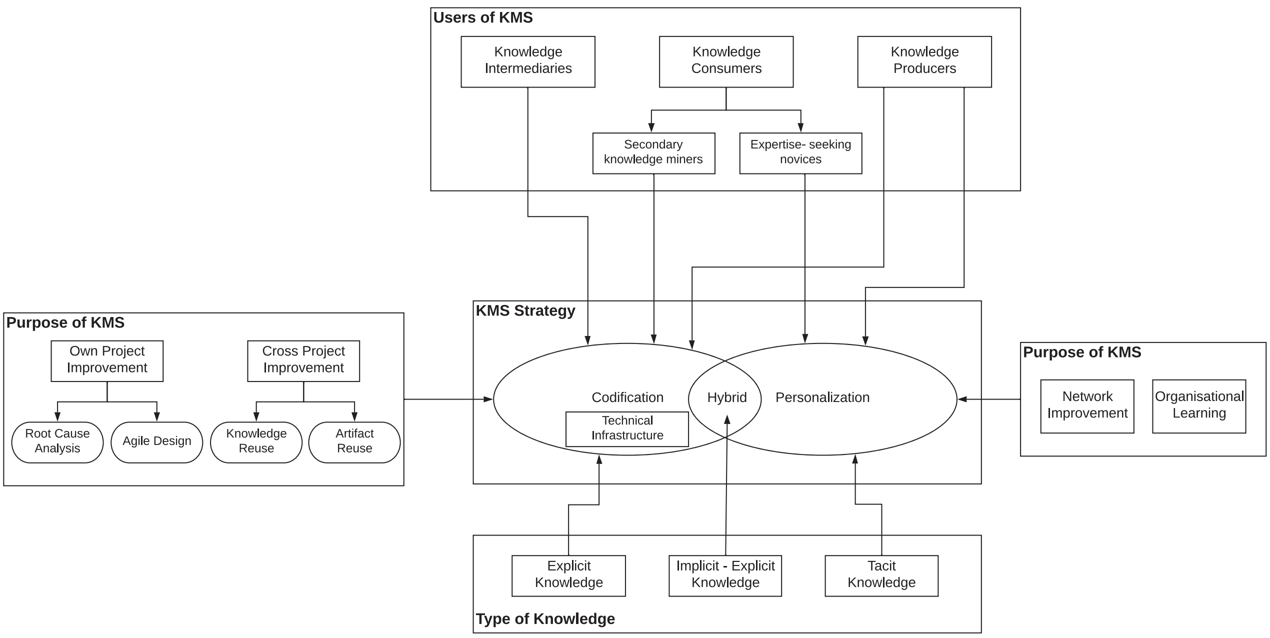

Figure 2. An illustration of the knowledge management framework.

Zave (1997), requirements engineering is also concerned with the evolution of the relationships among the functions and the constrains of a system. As such, requirements immediately become a tool for knowledge reuse, as they provide a common ground for comparing different systems and pointing to similarities between games. These similarities can be used either to improve future game development, as domain specific knowledge (Callele, Neufeld, & Schneider, 2005), or to reuse the outcome of previously created games to analyse a current issue.

The second phase is the *game design*. From a KM perspective, game design is concerned with the proper structure and documentation, which, in turn, can determine whether the new game is actually required or not, and thus whether previously obtained results can be used with minimal resources (Roungas et al., 2018c).

The third phase is *validation*. From a KM perspective, validation is concerned with meticulously documenting the validation process and has a twofold benefit for stakeholders: i) they can ascertain, with rather minimal effort, whether the results of the game can be used for the intended purpose, and ii) they can, again with much less effort, perform their own validation study and hence, use the game for slightly or completely different purposes (Roungas et al., 2018c).

The fourth phase is *game sessions*, which can be seen as a game instantiation. In object oriented programming terms (Rentsch, 1982), the game can be seen as a class with the rules and general guidelines of how the game works, whereas the game session can be seen as an instance of this class. A game is usually designed once (involving several iterations) but can be played multiple times with a similar or a completely different setup.

6.1.2. Implicit/tacit knowledge

Unlike explicit knowledge, tacit knowledge is not so straightforward to capture and manage. A database and a filesystem most probably would not be adequate to tackle the underlying challenges. Therefore, different methodologies, which might also result in different approaches with regards to the implementation of the KMS, are needed. Although literature is not exhaustive on how to capture and manage tacit knowledge, and how to convert this tacit knowledge in to explicit knowledge, several approaches have been proposed. Some of the most common techniques are:

- *Causal Maps*: Causal maps are interpretations of individuals" or groups" beliefs about causal relationships (Markíczy & Goldberg, 1995). Causal maps have been proven to be an effective tool for the elicitation of tacit knowledge for a variety of reasons, e.g., allowing to focus on action, eliciting context dependent factors etc. (Ambrosini & Bowman, 2001).
- *Semi-structured interviews*: While the purpose and structure of such an interview is predetermined, the essence of the "semi-structure" lies on the fact that interviewees are encouraged to answer questions by telling stories (Ambrosini & Bowman, 2001). The story telling nature of these interviews allows people to manage the collective memory of an organisation (Boje, 1991), frame their experiences (Wilkins & Thompson, 1991), and reflect on the complex social web of an organisation (Brown & Duguid, 1991).
- *Q-methodology*: In a nutshell, in Q-methodology the interviewee sorts a series of items/statements throughout a continuum (e.g. from strongly disagree to strongly agree) that is approximately normally distributed, in the sense that more of these statements are placed close to the neutral area than in the two edges of the continuum. An brief example of Q-methodology was shown in Section 5, where more detail is provided by Angeletti (2018).
- *Metaphors*: Various scholars argue that the use of metaphors can serve to transmit tacit knowledge (Ambrosini & Bowman, 2001; Martin, 1982) and since metaphors allow different ways of thinking, people may be able to explain complex organisational phenomena (Tsoukas, 1991). The term "metaphor" indicates the transfer of information from a relatively familiar domain to a relatively unknown domain (Tsoukas, 1991).
- *Social media*: The most ancient form for exchanging knowledge in general (Gurteen, 1998), and tacit knowledge in particular, is the use of dialog. This is perhaps why social media have become prominent on how people interact not only at a personal but also at a professional level. While research is still relatively scarce in this area, the use of social media sounds indeed promising for tacit knowledge sharing, since it encompasses interactive and collaborative technologies (Panahi, Watson, & Partridge, 2012).

6.2. Strategy, purpose, and users of KMS

The Strategy, Purpose, and Users of a KMS are crucial building blocks for KM and defining the structure of a KMF. An introduction to these elements is provided below.

6.2.1. Strategy

By looking into management consulting firms, Hansen, Nohria, and Tierney (1999) distinguished two KM strategies, which in turn heavily influence the final implementation of the KMS. These strategies are called *Codification* and *Personalisation*.

Codification stores any acquired knowledge and makes it available for reuse. Thereby it is isolated from its source, and should be preferred when people want to learn from past projects and apply this knowledge in the future (secondary knowledge miners) (Markus, 2001).

Personalisation is the exchange of knowledge that has been acquired in the past through one-to-one conversations and brainstorming sessions; it is a way to promote discussion and exchange of ideas and knowledge between people in a more personal manner, and should be preferred when people can benefit from experts" opinions (expertise-seeking novices) (Markus, 2001).

6.2.2. Purpose

There are various reasons for which an organisation would want to build a KMS. The most common ones are root-cause analysis, own project improvement, cross-project improvement, and network improvement.

Root-cause analysis is concerned with the establishment of strict and precise protocols to be in place, in order to help with the examination of problems or failures that might occur throughout the lifecycle of a game or due to decisions made based on a game (Latino, Latino, & Latino, 2016).

Own project improvement is concerned with the utilisation of the knowledge acquired during the lifecycle of a game to improve the game itself (Cockburn, 2006) and/or the project for which the game was built (Roungas et al., 2018c).

Cross-project improvement is concerned with the utilisation of the knowledge acquired during the lifecycle of a game to improve other game projects, current or future. A KMS can influence a current or future project either explicitly, by directly applying the acquired knowledge in another project, or implicitly, by creating added value (Spender, 2008), perhaps even a paradigm shift, within the organisation, which changes its modus operandi, and consequently influences any game project thereafter.

Network improvement is concerned with the utilisation of the KMS to strengthen the relationships of individuals and teams within an organisation, especially in large organisations, by bringing awareness of the totality of knowledge possessed within.

6.2.3. Users

Regardless of its type and purpose, the primary function of a KMS is to manage and disseminate knowledge to people, i.e. users. Therefore, users are at the centre of a KMS and any frameworks aiming at building a KMS should put users first. While there might be several stakeholders in a KMS, there are three main categories of users involved, knowledge producers, knowledge intermediaries, and knowledge consumers.

Knowledge producers are defined as the people that contribute their knowledge to the KMS. Incentives should be provided, in order for the knowledge producers to frequently and effectively share their knowledge and expertise. Moreover, knowledge producers should be experts in their respective field, since a person who aims at using knowledge previously acquired shall be confident of the expertise of the knowledge producers, and thus trust their respective findings (Watson & Hewett, 2006).

Knowledge intermediaries are the people that manage the knowledge, by indexing, summarising, and objectifying (to the extent that this is possible and appropriate).

Knowledge consumers are the end users of the KMS, thus the ones that benefit from it. Depending on the type and the purpose of the KMS, knowledge consumers can be the game designers, project managers, investigators, researchers, and even the participants of a game.

6.3. Application of KMF

The KMF has been applied to three case studies in the Railway Sector for further validation, two in The Netherlands and one on the European level (Authors, 2018). The analysis of the case studies reveals that the proposed KMF can cover the majority of knowledge generated in and around these games. However, the implementation of such a KMF into a fully functional KMS seems, and usually is, labour intensive. Nevertheless, it is evident both from theory and from the case studies examined that games produce different types and quality of knowledge. Particularly, the games that are part of the three case studies are designed for testing changes in the railway infrastructure, resulting in a strong focus on the debriefing after each game session. In turn, debriefing becomes the primary source of knowledge, especially for tacit knowledge. Hence, capturing all knowledge from games gives new opportunities for validity assessments at a higher level of detail, which both complements and puts pressure on the current sense-making approaches (van den Hoogen, Lo, & Meijer, 2014).

6.4. Final remarks on the KMF

Knowledge is the prime component of any KMS, hence it holds the lion"s share when analysing games. Nevertheless, just knowledge is not enough to build a KMS; the strategy, purpose, and potential users of the KMS should also be understood and taken into account. In effect, the purpose and the users of the KMS heavily influence how knowledge from games is captured, stored, and disseminated. Moreover, the purpose of the KMS defines its potential users and particularly the knowledge consumers.

The proposed framework provides general guidelines on the components to consider for the development of a KMS. Specific details on how to develop the KMS are dependent on the organisation culture itself and, as mentioned above, the users that support and use the KMS. Moreover, the purpose for which an organisation builds a KMS depends heavily on its maturity with regards to knowledge management. In this context, "mature" means that the organisation has the "know-how" of managing knowledge, which allows it to follow a top-down approach on the design of the KMS, thus starting by first defining the purpose and then gathering the required data. As a contrast, "immature" means that the organisation follows a bottom-up approach on the design of the KMS, thus starting by first gathering data, and then defining the purpose of the KMS based on the quality of the knowledge produced from the acquired data.

7. Conclusion

This paper started by clarifying the epistemology that governs games for P&DM. Then, through literature review, gaps in these games were identified, and solutions were proposed to address them. Four areas were identified where gaps exist within game development and usage: design, validation, game sessions, and knowledge management. For *design*, a framework for formalising game design based on game theory was proposed. Further research could focus on the application, fine-tuning and validation of the framework in domains other than the railways. For *validation*, the additional steps needed for the validation of P&DM games were acknowledged, especially the validation of the Simulation Layer in relation to the Game Layer, for which empirical and analytical methods should be combined. For the *game sessions*, interviews with experts identified a clear list of "do"s and don"ts" for the success of games for P&DM. For *knowledge management*, a framework for the management of knowledge produced by and in games was proposed. A next step would be the implementation of the framework into a full scale knowledge management system to fine-tune and validate the framework as well as demonstrate its operational capabilities. In addition to identifying the gaps in the four areas within game development and usage, a connection between these areas was established, showing how they are intertwined and thus affecting one another. Each of these four areas and their interconnections show the complexity of developing and using games and, as a result, the interdisciplinary approach that this requires. The identified problems and subsequently the proposed solutions vary from purely analytical to purely social, stressing the need for seamless cooperation between the analytical and design communities.

Disclosure statement

No potential conflict of interest was reported by the authors.

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